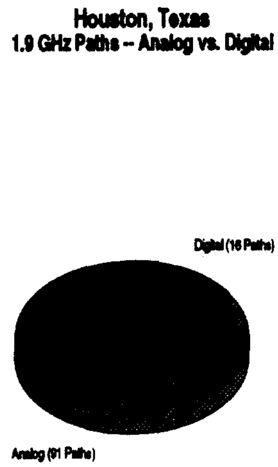


Figure 5

Source: FCC
Date: 10/91

Transition Methodology

The 6540 - 6870 MHz allocation was the candidate for the transition band due to the following considerations:

* Bandwidth and channel capacity at 6.7 GHz are consistent with 1.9 GHz.

* The 6.7 GHz band supports short, medium, and long haul systems.

* Eligibility requirements at 6.7 GHz are consistent with 1.9 GHz.

* Stringent interference protection criteria for 6.7 GHz are specified in FCC Part 94.63 and Telecommunications Industries Association Bulletin 10-E.

* Mature technology and manufacturer support exists for the 6.7 GHz band as evidenced by the 8,300 paths in service.

As previously mentioned, the Houston 6540 - 6870 MHz environment satisfied the high density congestion requirement necessary to challenge the simulation. Houston also represented the highest density 6.7 GHz congested environment combined with the absence of significant terrain features.

The next step was to define the radio and antenna system parameters that would form the basis of the operational characteristics for each 1.9 GHz path being transitioned to 6.7 GHz.

It was also necessary to define where within the Houston boundary area to begin the interference prediction, interference analysis and resolution, and frequency coordination to transition paths from 1.9 GHz to 6.7 GHz.

Each of these are defined on the following page.

## Path Parameters for Transitioned 6540 - 6870 MHz Paths

All 1.9 GHz paths within the simulation boundary were translated into typical 6.7 GHz path parameters. The translated parameters at 6.7 GHz are shown below:

| | |
|---|---|
| Coordinates & Ground Elevations | Identical to 1.9 GHz Paths |
| Transmission Line Loses | Identical to 1.9 GHz Paths |
| Antenna Centerlines | Identical to 1.9 GHz Paths |
| Antenna Diameters | Identical to 1.9 GHz Paths |
| Loadings | Identical to 1.9 GHz Paths |
| Transmitter Characteristics | Exhibit 1 for Analog Paths |
| | Exhibit 2 for Digital Paths |
| Receiver Characteristics | Exhibit 1 for Analog Paths |
| | Exhibit 2 for Digital Paths |

Transmitter and receiver characteristics for the transitioned 6.7 GHz paths are shown in Exhibits 1 and 2. The performance characteristics of these typical 6.7 GHz radios were derived from FCC technical standards and surveying predominant radio manufacturer's filter characteristics and threshold-to-interference (T/I) requirements. The threshold and filter performance characteristics are typical values within 3 dB of worst-case.

Antenna system performance characteristics (gain and discrimination) for the 6.7 GHz transitioned paths were derived from surveying predominant antenna manufacturer's product lines. Typical radiation pattern envelopes for parabolic, shrouded parabolic, and enhanced shrouded antennas were defined for the various antenna diameters deployed on transitioned 6.7 GHz paths. A minimum antenna diameter of 8 feet was required on the transitioned 6.7 GHz paths. This was necessary to satisfy off-beam radiation suppression standards per FCC Part 94.75.

## Transition Simulation

To define the physical starting point for the transition simulation, the population of 1.9 GHz paths within the Houston coordination boundary were overlaid on the existing 6.7 GHz environment. This represented the environment for conducting the transition simulation. Areas of concentrated path activity between the original 1.9 GHz and 6.7 GHz environments were similar. The Houston central business district represented the highest concentration of combined paths. The simulation began here.

With the operational parameters for the transition paths specified and the starting point for the simulation established, the next step was to initiate the simulation model.

**Exhibit 1**
**6.7 GHz Analog Radio Specifications**

General:

| | |
|---|---|
| Frequency Range: | 6.525 - 6.875 GHz |
| Channel Capacity: | 120, 132, 300, 480, 600 |
| Modulation: | FM |
| T/R Separation (same path): | 160 MHz |
| Minimum T/R Separation (same path): | 80 MHz |
| Minimum T/R Separation (co-site): | 40 MHz (Analog-Analog)<br>50 MHz (Analog-Digital) |

Transmitter:

Transmitter Power Output (Antenna Port): +31.0 dBm
Frequency Stability: ± 0.005%

Receiver:

| | |
|---|---|
| IF Frequency: | 70 MHz |
| RF Filter Bandwidth: | 30 MHz |
| Receiver Overload: | -27 dBm |

| Channel Capacity | Emission Designator | Threshold (dBm) | IF Bandwidth (MHz) |
|---|---|---|---|
| 120/132 | 5,000 F9 | -93.0 | 10.0 |
| 300 | 5,000 F9 | -87.8 | 10.0 |
| 300 | 10,000 F9 | -91.0 | 18.0/14.0 |
| 480 | 10,000 F9 | -85.0 | 18.0/14.0 |
| 600 | 10,000 F9 | -81.0 | 18.0/14.0 |

IF Filter Selectivity:

5 MHz Emission Bandwidth Radio:

| Frequency Separation (MHz) | 5 | 10 | 15 | 20 |
|---|---|---|---|---|
| Selectivity (dB) 10 MHz IF Filter | 3 | 18 | 14 | 15 |

10 MHz Emission Bandwidth Radio:

| Frequency Separation (MHz) | 5 | 10 | 15 | 20 |
|---|---|---|---|---|
| Selectivity (dB) 18 MHz IF Filter | 0 | 4 | 14 | 30 |
| Selectivity (dB) 14 MHz IF Filter Refers to Upgraded Filter | 0 | 25 | 25 | 37 |

**Exhibit 2**
**6.7 GHz Digital Radio Specifications**

General:

| | |
|---|---|
| Frequency Range: | 6.525 - 6.875 GHz |
| Emission Bandwidth: | 5 MHz, 10 MHz |
| Channel Capacity: | 8 DS1 (5 MHz Bandwidth)<br>28 DS1 (10 MHz Bandwidth) |

| | |
|---|---|
| Standard T/R Separation (same path): | 160 MHz |
| Minimum T/R Separation (same path): | 80 MHz |
| Minimum T/R Separation (co-site): | 50 MHz (Digital-Digital)<br>50 MHz (Analog-Digital) |

Transmitter:

Transmitter Power Output: 31.0 dBm (10 MHz Bandwidth)
Transmitter Power Output: 25.0 dBm (5 MHz Bandwidth)
Frequency Stability: ± 0.005%
Transmitter Emitted Spectrum: Complies with FCC Part 94.71

Receiver:

5 MHz Bandwidth:

Threshold $10^{-6}/10^{-3}$ BER: -79.0/-84.0 dBm

| Frequency Separation (MHz) | 0 | 5 |
|---|---|---|
| Threshold-to-Interference (T/I) dB | 25 | -15 |

10 MHz Bandwidth:

Threshold $10^{-6}/10^{-3}$ BER: -74.0/-77.0 dBm

| Frequency Separation (MHz) | 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| T/I values like signal (dB) | 38 | 29 | 20 | 2 |
| T/I values CW signal (dB) | 38 | 28 | -10 | -20 |

Interference Prediction and Resolution

Telecommunications Industry Association Bulletin 10-E interference prediction methods and FCC Part 94.63 interference avoidance criteria were used in analyzing interference scenarios between the transitioned 6.7 GHz paths and the existing 6.7 GHz environment.

The primary objective in interference resolution was to secure interference-free frequencies on transitioned 6.7 GHz paths while minimizing changes from the prescribed transition parameters outlined previously.

The priority in resolving predicted interference between transitioned and existing 6.7 GHz paths are listed below:

1. Free space loss
2. Antenna discrimination and cross-polarization
3. Over-the-horizon blockage
4. Transmitter attenuation for transitioned path
5. Filter upgrade for transitioned path
6. Antenna upgrade for transitioned path
7. Combinations of the above

In the event the predicted interference between transitioned and existing 6.7 GHz system could not be resolved by the means mentioned above, the transitioned path would be failed.

Assignment of interference-free 6.7 GHz frequencies commenced by first analyzing the transitioned paths in the Houston downtown area and then spanning out following the backbone routing on an owner by owner basis.

As each transitioned 6.7 GHz path was assigned frequencies, it became part of the environment (along with existing 6.7 GHz systems) considered in conducting interference analysis and frequency assignment for subsequent transitioned paths.

The summary that follows reflects the results of simulating the transition of 1.9 GHz paths in Houston to 6.7 GHz.

## Transition Results

Results of interference analysis, interference resolution, and frequency assignment in the transition simulation of 1.9 GHz paths in Houston to 6.7 GHz are summarized below:

| | |
|---|---|
| Paths Analyzed for Transition from 1.9 GHz to 6.7 GHz | 107 |
| Paths Successfully Transitioned | 103 |
| Paths Failed Transition | 4 |

The frequency assignments for the 103 transitioned paths satisfied intersystem non-interference with respect to the existing 6.7 GHz environment and intrasystem non-interference with respect to the transition environment.

The paths that failed the transition to 6.7 GHz were precluded due to interference conflicts with the existing 6.7 GHz environment, not the transition environment.

The summary of antenna and filter upgrades necessary to transition the paths is shown below:

| | |
|---|---|
| Paths Successfully Transitioned | 103 |
| Paths Requiring Antenna Upgrades | 7 |
| Paths Requiring Filter Upgrades | 6 |

The summary of transmitter attenuation and attenuation types required to transition the paths are as follows:

| | |
|---|---|
| Paths Successfully Transitioned | 103 |
| Paths Attenuated to Meet FCC Short Path Power Limits | 14 |
| Paths Attenuated to Protect Existing 6.7 GHz Receivers | 7 |
| Paths Attenuated to Prevent Receiver Oversaturation | 3 |

The attached spreadsheet (Exhibit 3), sorted by owner, reflects comprehensive results of the transition model. A glossary of terms referenced on the spreadsheet immediately follows.

## Exhibit 3
## 6.7 GHz Transition Simulation Spreadsheet

| OWNER | NO. OF PATHS | NO. OF CASES FOUND | AVERAGE PATH LENGTH (Miles) | AVERAGE RX LEVEL (dBm) | AVERAGE FADE MARGIN (dB) | WORST CASE FADE MARGIN (dB) | NO. OF PATHS WITH ATTENUATION | NO. OF PATHS WITH FILTER UPGRADES | NO. OF PATHS WITH ANTENNA UPGRADES | PATHS FAILED |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Shell Communications | 16 | 5,047 | 25.9 | -32.9 | 56.5 | 47.9 | 4 | 3 | 2 | 0 |
| 2 Chevron Industries, Inc. | 8 | 1,559 | 20.0 | -32.0 | 51.9 | 38.5 | 1 | 0 | 1 | 0 |
| 3 Coastal States Management | 6 | 1,386 | 19.6 | -31.7 | 57.7 | 52.9 | 1 | 0 | 0 | 0 |
| 4 Missouri Pacific | 6 | 1,120 | 13.6 | -30.1 | 57.9 | 50.6 | 2 | 0 | 0 | 0 |
| 5 Tenneco Communications | 6 | 1,687 | 21.1 | -30.1 | 50.9 | 48.2 | 1 | 0 | 1 | 0 |
| 6 Trunkline Gas | 6 | 2,041 | 22.9 | -32.2 | 58.8 | 55.3 | 1 | 0 | 0 | 0 |
| 7 Valero Communications | 6 | 2,171 | 18.9 | -29.9 | 61.1 | 55.9 | 1 | 1 | 1 | 1 |
| 8 AT&SF Railroad | 5 | 941 | 19.5 | -29.1 | 61.9 | 59.7 | 0 | 0 | 0 | 0 |
| 9 Houston Pipeline Company | 5 | 1,615 | 18.0 | -32.5 | 58.5 | 56.3 | 2 | 0 | 0 | 0 |
| 10 Seadrift Pipeline | 5 | 838 | 24.4 | -32.3 | 58.7 | 55.6 | 0 | 0 | 0 | 0 |
| 11 Transcontinental Gas | 5 | 1,687 | 26.9 | -30.3 | 54.3 | 53.2 | 1 | 0 | 1 | 0 |
| 12 Amoco Corporation | 4 | 1,046 | 21.6 | -35.8 | 43.2 | 40.8 | 0 | 0 | 0 | 0 |
| 13 Exxon | 4 | 1,717 | 14.1 | -30.0 | 44.0 | 44.0 | 1 | 0 | 1 | 3 |
| 14 Galveston County | 4 | 785 | 8.2 | -34.5 | 49.6 | 43.4 | 3 | 0 | 0 | 0 |
| 15 All American/Union Oil | 3 | 830 | 6.1 | -34.3 | 54.7 | 49.4 | 3 | 2 | 0 | 0 |
| 16 UCAR Pipeline | 3 | 1,159 | 23.6 | -31.6 | 59.4 | 58.6 | 0 | 0 | 0 | 0 |
| 17 Arco Communications | 2 | 566 | 12.5 | -33.2 | 45.9 | 44.2 | 1 | 0 | 0 | 0 |
| 18 Oasis Pipeline | 2 | 836 | 22.3 | -32.5 | 58.6 | 57.3 | 0 | 0 | 0 | 0 |
| 19 Southern Pacific | 2 | 469 | 18.6 | -31.9 | 51.1 | 45.3 | 0 | 0 | 0 | 0 |
| 20 Sun Service Corporation | 2 | 355 | 24.6 | -30.5 | 60.6 | 57.2 | 0 | 0 | 0 | 0 |
| 21 American Nat. Ins. | 1 | 309 | 23.4 | -34.9 | 44.1 | 44.1 | 0 | 0 | 0 | 0 |
| 22 Brazos Electric Power | 1 | 195 | 7.3 | -31.2 | 53.8 | 53.8 | 1 | 0 | 0 | 0 |
| 23 Dow Chemical | 1 | 400 | 3.5 | -33.5 | 40.5 | 40.5 | 1 | 0 | 0 | 0 |
| 24 Houston Light & Power | 1 | 182 | 13.3 | -28.0 | 63.0 | 63.0 | 0 | 0 | 0 | 0 |
| 25 Lower Co River Authority | 1 | 199 | 21.3 | -29.1 | 51.9 | 51.9 | 0 | 0 | 0 | 0 |
| 26 Mobil Pipeline | 1 | 211 | 15.5 | -27.4 | 63.6 | 63.6 | 0 | 0 | 0 | 0 |
| 27 Texas Municipal Power | 1 | 158 | 17.3 | -35.6 | 49.4 | 49.4 | 0 | 0 | 0 | 0 |
| TOTALS | 107 | 29,509 | 19.8 | -31.9 | 54.4 | 38.5 | 24 | 6 | 7 | 4 |

Glossary of Spreadsheet Terms

Owner and Number of Paths - Number of licensed and applied-for 1.9 GHz paths within the Houston transition boundary. Owners are listed in descending order with respect to their 1.9 GHz path count.

Number of Cases Found - Number of predicted interference cases resulting from transitioning each owner's 1.9 GHz paths to 6.7 GHz.

Average Path Length - The sum of transition path distances divided by the total number of transition paths analyzed.

Average Receive Level - The sum of each transitioned 6.7 GHz path's receive signal level (computed after all required path modifications in order to successfully transition the path) divided by the total number of receivers that transitioned successfully.

Average Fade Margin - The summation of each transitioned 6.7 GHz receiver's fade margin divided by the total number of receivers.

Worst Case Fade Margin - The lowest fade margin computed for a receiver that was successfully transitioned.

Number of Paths with Attenuation - Number of paths that required additional attenuation in order to satisfy either non-interference objectives, FCC EIRP restrictions, or to avoid receiver oversaturation.

Number of Paths with Filter Upgrades - Number of transitioned paths that required an upgraded filter to avoid potential threshold degradation.

Number of Paths with Antenna Upgrades - Number of transitioned paths that required either a larger diameter or shrouded antenna or both in order to satisfy non-interference objectives.

Paths Failed - Number of paths that could not be transitioned due to unresolved interference cases into or from the existing 6.7 GHz environment.

## Conclusions

The conclusions from modeling the transition of 1.9 GHz paths to 6.7 GHz in Houston are separated into factors contributing to the successful transition of paths and factors limiting the overall application of the model.

Four dominant factors contributed to successfully transitioning 1.9 GHz paths to 6.7 GHz.

1. Bandwidth Availability

   The additional channelized bandwidth at 6.7 GHz, more than double that available at 1.9 GHz, facilitated transitioning paths to 6.7 GHz by creating greater flexibility and options in frequency planning.

   Channelized bandwidth comparisons for 1.9 and 6.7 GHz are shown below:

| Band (MHz) | Available Bandwidth (MHz) |
|---|---|
| 1850 - 1990 | 140 |
| 6540 - 6870 | 330 |

2. Antenna System Performance

   Antenna system performance at 6.7 GHz contributed to interference resolution in transitioning 1.9 GHz paths to 6.7 GHz due to improved directivity and discrimination characteristics.

   Antenna performance comparisons for typical 1.9 and 6.7 GHz eight foot antennas are listed below:

| | 1.9 GHz | 6.7 GHz |
|---|---|---|
| Antenna Beamwidth (degrees) | 4.5 | 1.3 |
| Co-Pol Discrimination (dB), 45° | 32 | 45 |
| Front-to-Back Ratio (dB) | 39 | 49 |

Conclusions (cont.)

3. Free Space Attenuation

The additional 11 dB free space path loss between interfering transmitters and victim receivers at 6.7 GHz compared to 1.9 GHz mitigated interference hazards between the transitioned and existing 6.7 GHz paths.

Free space path loss is computed as:

Free space loss (dB) = 96.6 + 20 log (d) + 20 log (f)

Where d = Path length in miles
f = Frequency in GHz

Free space loss comparison between 1.9 GHz and 6.7 GHz is computed as:

Additional free space path loss at 6.7 GHz (dB) = 20 log (f2/f1)
= 20 log (6.7/1.9)
= 10.94 dB

Where f1 = 1.9 GHz
f2 = 6.7 GHz

4. Control of the 6.7 GHz Transition Environment

The model was based on the simultaneous interference analysis and frequency coordination between 107 transitioned paths and the existing 6.7 GHz environment. Simultaneous interference analysis of the transitioned paths enabled optimum frequency planning and frequency assignments. This is due to the ability to modify previous frequency assignments on the transitioned 6.7 GHz paths when conducting interference analysis and interference resolution on subsequent transitioned paths. Controlling the transition environment maximized the degree of success in securing bandwidth on transitioned paths while minimizing system upgrades necessary to satisfy non-interference.

## Conclusions (cont.)

Four factors limit the application of the transition model.

1. System Reliability at 6.7 GHz

   The simulation for transitioning 1.9 GHz paths into the 6.7 GHz band was guided by TIA and FCC interference avoidance and frequency coordination considerations. The simulation was not a reliability analysis, system design, or network performance model.

2. Cost

   A major concern to microwave users is the cost associated with transitioning 1.9 GHz paths to 6.7 GHz. The scope of the transition simulation was limited to identifying bandwidth for transitioned paths and resolving interference hazards into and from existing 6.7 GHz paths. Detailed spreadsheets have been prepared for each owner of 1.9 GHz paths in the Houston boundary area. These spreadsheets are expected to facilitate economic modeling of transition costs.

3. Tower Loading

   Tower loading and antenna mounting considerations were not considered in conducting interference analysis and frequency assignment on the transitioned 6.7 GHz paths. Significant tower reinforcement and bracing of antennas may be required to change grid antennas at 1.9 GHz to solid or shrouded antennas (possibly with diversity) at 6.7 GHz.

4. Applicability in Other Geographic Areas

   The results of this transition simulation may not be identical in all geographic areas. In each geographic area the level of success or failure of the model will be dictated by the distribution of existing 1.9 GHz and 6.7 GHz paths, the degree of frequency congestion, and the extent to which the transitioned 6.7 GHz environment can be controlled.

## Summary

The model described in this paper accurately quantifies bandwidth availability at 6.7 GHz for potentially displaced 1.9 GHz systems. Due to its flexibility, the model can be applied to quantify bandwidth availability in other allocations and geographic areas as well.

## References


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